



Range extension and highest elevational populations of *Natrix tessellata* in Slovakia

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Abstract.—The Dice Snake, *Natrix tessellata* (Laurenti 1768), is one of five snake species living in Slovakia. Because this species is understudied, there is little known about its distribution in this country. Slovakia represents the northern limit of its occurrence in Europe. In the context of published and unpublished distribution records and our personal database, we report the first records of this species from the upper Váh River in the Liptovská Basin representing the species range extension in Slovakia. The newly discovered population also represents the highest altitudinal record for *N. tessellata* in the country. We discuss possible reasons for their occurrence in this region.

Keywords. Dice Snake, Natricidae, distribution, highest elevation, new records, Central Europe

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Introduction

The Dice Snake, *Natrix tessellata* (Laurenti 1768), is a well-known snake species with a wide distribution, ranging from Central Asia and northeastern Africa to Central Europe (Gruschwitz et al. 1999; Mebert 2011 and literature therein). Throughout this huge area, nine well-supported and highly divergent lineages were detected which suggests that this snake has experienced a complex radiation history (Guicking et al. 2009; Guicking and Joger 2011). Central Europe is inhabited by a single “European lineage” which probably originated from glacial refugial populations in the Balkan Peninsula and historically expanded north along the Danube river system during the Holocene (Atlantikum: Guicking et al. 2009; Guicking and Joger 2011; Vlček et al. 2011). Today, in central-eastern Europe, *N. tessellata* is a rare thermophilic species with a semiaquatic lifestyle. It prefers suitable habitats in relatively warmer river valleys, small streams and water reservoirs that are well exposed to solar radiation and contain some undamaged natural vegetation. In particular, sites with rocky slopes, rubble, or dry walls, some even near roads and railways, are suitable for overwintering, oviposition, daily shelter, and thermoregulation (Rehák 1992a; Mebert 2011 and literature therein). This species has a wide altitudinal range in Europe east of the Caucasus from sea level to >1,000 m asl in mostly

southern regions (Rehák 1992a), with the highest record at 1,475 m at Livinallongo, Venetia, Italy (Bruno and Mageri 1990, cit. in Gruschwitz et al. 1999).

The Dice Snake is a protected species in Slovakia (Vulnerable, according to Kautman et al. 2001). Its habitat corresponds to those generally known for this species in Central Europe north of the Alps (e.g., Gruschwitz et al. 1999; Mebert 2011) with a maximum elevation up to 400 m asl (Lác 1968; Rehák 1992a). Although Slovakia represents the regional northern border of the Dice Snake, there is a lack of faunistic research on this species in this country. The occurrence of *N. tessellata* here is probably relatively continuous, but it is more common to observe this species in southern and central regions, where it is associated with the main rivers (Danube, lower and middle Váh, Hron, Slaná, Hornád, Torysa, and Bodrog; Lác and Lechovič 1964; Lác 1968; Rehák 1992a). Occurrence and dispersion of the Dice Snake to northern and upper parts of Slovakia along river systems have not been clearly proven so far. In the river basin of Váh the historically most northern findings were recorded near the village of Horné Srnie (Lác and Lechovič 1964) and in Žilina – Hričov Reservoir (Dobšínský, pers. comm.). Regional northern and probably isolated populations were recently discovered in close proximity to Slovak locations in north-eastern parts of the Czech Republic and southern Poland (Vlček et al. 2010, 2011). However, the

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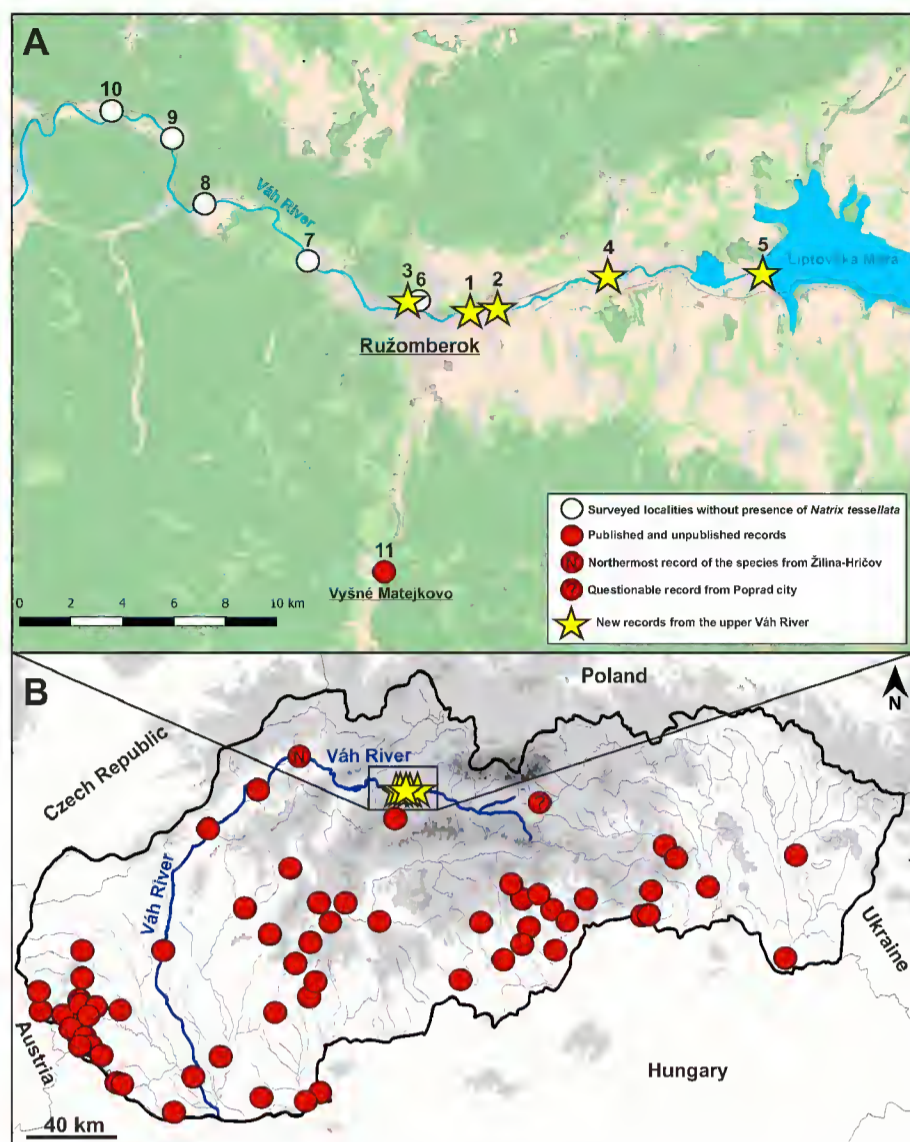


Fig. 1. Distribution and range extension of *Natrix tessellata* in Slovakia. **(A)** Locations surveyed in the vicinity of Ružomberok and Liptovská Basin. **(B)** Records of the species in the country. Black line shows cut out area of new locations while **(A)** is the same area but enlarged. 1 – Ružomberok, 2 – Lisková, 3 – Ružomberok – Rybárpole, 4 – Liptovská Teplá, 5 – Liptovská Mara, 6 – Ružomberok, 7 – Hrboltová, 8 – Hubová, 9 – Stankovany, 10 – Kraľovany, 11 – Vyšné Matejkovo.

overall situation in Slovakia is not completely understood and insufficient information is available about the current distribution and habitat preference of *N. tessellata*.

Methods and Materials

In this work, we provide an update on the distribution of *N. tessellata* in Slovakia with the first record of this species from upper Váh River (Fig. 1). We conducted seven field trips (2014–2017) to the region between Kraľovany town and Liptovská Mara Dam to find new records of the species (see Table 1, Fig. 1A). To present the current distribution of the species we combined the unpublished authors' database with published records of *N. tessellata* from Slovakia (Fig. 1B).

Basic morphometric and meristic data, presented in Table 2, were taken from a few individuals from two locations (see Table 1, loc. 2, 3). A caliper was used for head measurements – head length (HL), head width (HW), and mouth length (ML), and a tape band was applied to record body measurements – body length (SVL), tail length (TL), and total length (TotL). Several meristic characteristics were also taken: number of cephalic scales – preocular (PREOC), postocular (POSTOC), supralabial (SUPL), and sublabial (SUBL), also includ-

ing the number of ventral (VENT) and subcaudal scales (SUBC), and dorsal scale rows (DORS). Anomalies like split ventral scales, fused subcaudal scales, inserted cephalic scales etc., as well as coloration of the ventral side of the body (white, yellow, or orange) and on the upper side of the head (spotted or not) were also recorded. All individuals were photographed and then released in the same location.

Results

Based on approximately 300 observations from 70 localities, *N. tessellata* has a large and continuous distribution along main river systems across all southern and central parts of Slovakia (Fig. 1). Herein described populations in upper Váh River represent a regional northern limit of the main distribution range (Fig. 1B).

The presence of the Dice Snake along the upper Váh River was first documented by photography near Ružomberok town (49.080°N, 19.317°E; 477 m asl; loc. 1), where a juvenile was observed on 21 May, 2013 at the river bank of Váh and channel system of the company Mondi Packaging Ružomberok (Dobrota 2013, pers. comm.; Fig. 2D). Employees of the company reported to us the observation of individuals as early as 20 April, 2013. Since then, more juveniles and subadults of *N. tessellata* were observed by the employees in different parts of the company and the vicinity of the Váh River.

During our field trips we confirmed existence of a reproductive population with both adult and juvenile individuals. On 19 July, 2017, we recorded 14 individuals of different ages and sexes in two new locations near Ružomberok (Fig. 3). The first location was Lisková (49.084°N, 19.344°E; 482 m asl; loc. 2) where eight individuals (juveniles, subadults, and adults) were observed along or in the Váh River. At the second location, Rybárpole (49.087°N, 19.296°E; 473 m asl; loc. 3), only juveniles and one subadult were observed.

Some individuals from these populations had a lower number of supralabial scales (SUPL, listed in Table 2) when compared with individuals from other parts in Slovakia and the Czech Republic. Aside from this characteristic, none of the studied individuals have a significantly low or high number of other morphometric or meristic characteristics. On the other hand, we noticed some anomalies such as fused sublabial, inserted ventral, or fused subcaudal scales. In terms of all morphometric and meristic characteristics and ventral body coloration taken during field trips, we did not notice any important differences.

To obtain a better overview on situation of Dice Snakes in the upper Váh River, we asked local naturalists and fisherman for information. We obtained photographic evidence of an adult female Dice Snake in situ at Liptovská Teplá (49.096°N, 19.410°E, 501 m asl; loc. 4; Birček 2017, pers. comm.) about six km east from location 2, Lisková. This author also noticed one live



Fig. 2. Locations and habitat of *Natrix tessellata* near Ružomberok. **(A)** Location in Ružomberok where the first individuals were observed. **(B) (C) (D)** View on the habitat near Lisková village.

adult male and one dead adult individual near the dam Liptovská Mara (the largest dam in Slovakia; 49.093°N, 19.486°E; 554 m asl; loc. 5). We had attempted to find this species in Liptovská Mara during July 2017 but were unsuccessful. However, as these locations are close to each other, we expect the Dice Snake to occur throughout this part of the river. The locations described herein represent the currently highest elevations for *N. tessellata* in Slovakia. We also surveyed apparently suitable and lower locations between Ružomberok and to the west as far as Kral'ovany where any Dice Snakes were recorded.

The newly discovered population of *N. tessellata* in Slovakia is located 72 km eastwards from its previously northernmost known records (Žilina – Hričov Reservoir, personal observations). Banks on one side of the Hričov Reservoir are not accessible to people because of the steep slope, but on the other side of the shore there are some suitable places even for overwintering. Moreover, small ponds are in the vicinity of the reservoir, but we still cannot confirm the presence of a stable population here.

The newly discovered population inhabits a locally regulated river flowing from east to west, which is also a tributary of the Danube River that ultimately drains into the Black Sea. Around Ružomberok the river is approximately 40–60 m wide, 1–2 m deep with an average flow rate of about 30 m³s⁻¹. The river flow is partially modified with preserved natural parameters of riverbed, where

only the most damaged parts of the shore are repaired with stones or alternatively reinforced. The bottom of the river has unchanged stony and muddy parameters with gravel and stony base. Shore vegetation is continuous and predominantly intact (*Alnus* sp., *Salix* sp., *Populus* sp.) and with maximum surface shading of about 22%. To the east, the climate of the upper Váh River as far as Liptovská Mara Dam is typically moderate with an average annual air temperature of 6 °C. During the hottest month of the year (July) average temperature can vary between 16–17 °C. On only about 29 days per year does the temperature reach more than 25 °C. Average annual precipitation for this location is approximately 711 mm with the highest precipitation amounts in July (Šamaj and Valovič 1981). In the studied region (Liptovská Basin) there are known thermal springs that may affect local microclimate. The presence of prey is necessary for *N. tessellata* occurrence. Ichthyologically, the region from Žilina to Liptovská Mara Dam forms a foothill river zone with the occurrence of the following fish species: *Barbus barbus* (Linnaeus 1758), *Hucho hucho* (Linnaeus 1758), *Leuciscus cephalus* (Linnaeus 1758), *L. leuciscus* (Linnaeus 1758), *Oncorhynchus mykiss* (Walbaum 1792), *Perca fluviatilis* (Linnaeus 1758), *Thymallus thymallus* (Linnaeus 1758), *Salmo trutta* (Linnaeus 1758), and others (Mužik 2012). Another snake species *N. natrix* (Linnaeus 1758) lives here in syntopy with *N. tessellata*. On the bank of the river *Lacerta agilis* (Linnaeus 1758),



Fig. 3. Individuals of *Natrix tessellata* from the location in Lisková. (A) Adult female dorsal view. (B) Same individual in ventral view. (C) Overall view on juvenile individual. (D) Detail of the head on the same individual.

Coronella austriaca (Laurenti 1768), and *Vipera berus* (Linnaeus 1758) were also observed.

Discussion

The Dice Snake is known for its variation in the number of preocular, postocular, ventral, and subcaudal scales (Laňka 1978). There is a tendency to have a lower number of cephalic scales in Central Europe than in eastern regions of *N. tessellata* (Mebert 2011). Laňka (1978), Reháč (1989), and Moravec (2015) noticed that the most common number of preocular scales is two for specimens from the Czech Republic. In our case eight individuals from total 14 studied had two preocular scales at least on the one side of the head, although one individual from Lisková had four preoculars (Table 2), which is less common in Slovakia or in the Czech Republic. Normally, three or four postocular scales are the most common for Dice Snakes from Central Europe. Reháč (1989) found the presence of three and four postoculars in the Czech Republic, but in Lisková we counted five postoculars in one individual that can also be presented (Moravec 2015). In two individuals from Rybárpole we noticed six supralabials. According to Laňka (1978) it is not an anomaly to have such a small number of scales. A lower number of supralabials can be caused by fusing some scales together (Moravec 2015).

The Dice Snake is usually mentioned in Slovak (and

former Czechoslovak) literature as a common species around freshwater habitats, but only few locations are given in detail (e.g., Lác and Lechovič 1964; Lác 1968; Labanc 1972; Reháč 1992a; Uhrin et al. 1996, pers. comm.; Smolinský 2004; Májský 2009; Lác et al. 2017). Overall evaluation of published and unpublished sources showed that *N. tessellata* ranges from Záhorská lowland through southern and central Slovakia to eastern parts of the country. Data from peripheral eastern and western parts of the country have not been verified recently. Our data showed that the species was recorded along the river tributaries of Morava (near the confluence with the Danube), Danube, Little Danube, Žitava, Váh, Nitra, Hron, Ipeľ, Rimava, Blh, Slaná, Muráň, Bodva, Hornád, Laborec, and Bodrog, which corresponds with records reported in earlier literature (Lác and Lechovič 1964; Lác 1968; Lác et al. 2017), but we also extend the range knowledge with the new observations of this species (Fig. 1B). Our new records are not the northernmost in Slovakia (or in the Carpathians) as there are observations (Dobšínský, pers. comm.) from Žilina – Hričov Reservoir. All northern locations presented in the paper from Slovakia might be colonized by the species naturally. Increasing temperatures, appropriate regional temperature conditions, presence of structural elements like dry stone walls, deep rock mounds (offer shelter for digestion, ecdysis etc.; Carlsson et al. 2011), railway track constructions near water source, and reduced shore

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Table 1. An overview of *Natrix tessellata* records and surveyed locations in the vicinity of Ružomberok city. The numbers of locations correspond with Fig. 1A.

Locality number	Locality name	Coordinates		Elevation (m)	Observation	Source
		N	E			
1	Ružomberok	49.080	19.317	477	juveniles, subadults	Dobrota 2013, pers. comm.
2	Lisková	49.084	19.344	482	juveniles, subadults, adults	This study
3	Ružomberok - Rybárpole	49.087	19.296	473	juveniles, subadults	This study
4	Liptovská Teplá	49.096	19.410	501	one adult	Birček 2017, pers. comm.
5	Liptovská Mara	49.093	19.486	554	adults	Birček 2017, pers. comm.
6	Ružomberok	49.087	19.302	471	-	This study
7	Hrboltová	49.101	19.243	464	-	This study
8	Hubová	49.121	19.188	449	-	This study
9	Stankovany	49.144	19.172	437	-	This study
10	Kraľovany	49.153	19.139	429	-	This study
11	Vyšné Matejkovo	48.992	19.283	570	one adult	Hriadel, pers. comm.

vegetation represent elements that provide suitable sites for embryogenesis, ovipositing, thermoregulation, hibernation, and protecting against predators upon spring emergence (Conelli et al. 2011; Neumann and Mebert 2011; Strugariu et al. 2011). According to presence of these factors there can be found more suitable sites along Váh River for *N. tessellata* in future. We can still discuss observation of the species from Žilina – Hričov Reservoir. They probably do not form a reproductive population because stable presence of these snakes here is not well confirmed. Therefore, we should pay attention to these northern observations and take better effort for field work, especially in springtime, to explain the origin of the population living on the upper Váh River.

Our new records from the upper Váh River region increase the altitudinal distribution of *N. tessellata* in Slovakia above 500 m asl (Table 1). So far, the upper limit presented by Reháč (1992a) shows 400 m asl but most of the findings come from lower elevations. As is suggested by data from eastern Ukraine, Romania, or Austria, this species is able to colonize suitable valleys on the hill sides up to 1,000 m asl (Reháč 1992a). This should be studied in more detail but it seems that the limiting factor for distribution of *N. tessellata* in Slovakia is most likely a combination of elevation, local climate, and places for overwintering. In particular the lack of places for overwintering is characteristic for several regions of western or southwestern Slovakia where suitable river habitats are presented (wide slopes allowing an easy access to the water, shallow waters to forage fish, variable character of banks), however the species has never been recorded there (Lác 1968; Reháč 1992a; Kautman, pers. comm.).

In Central Europe, *N. tessellata* prefers shores where sediments, groups of stones, growing or fallen trees, and different small dams create many places with shallow water, open access to water, sunny areas, and shelters under the ground. These parts of the shore are necessary for permanent occurrence of the species in or near river valleys (Moravec 2015).

We assume that the population observed along the upper Váh River near Ružomberok is autochthonous and/or is partially formed by individuals migrating from lower parts of the river. This is consistent with the inhabited biotope and with the finding of individuals in different age stages (juveniles and adults). Moreover, we recorded an interesting museum specimen of *N. tessellata* from higher elevation than Ružomberok, collected on 30 April, 1938, leg. J. Jakubík, Vyšné Matejkovo, Revúca stream (48.992°N, 19.283°E, 570 m asl; loc. 11). This record is located approximately 11 km south of Ružomberok (Hriadel, pers. comm.). This finding was previously stored in the Liptov Museum in Ružomberok (Lác and Lechovič 1964), but the museum specimen has now been removed from the collection, so it is not possible to verify the record in detail.

However, why there is an established population is unclear. Hypothetically, we could suggest that this reproducing population in the upper Váh River could have a connection with the presence of geothermal waters and thermal springs that may affect local microclimatic conditions. The Dice Snake occupies a wide variety of water systems (Mebert 2011 and literature therein). As is discussed in Mebert and Masroor (2013), the presence of *N. tessellata* in high elevations of Pakistan may have a local

Table 2. Morphometric and meristic characteristics recorded from *Natrix tessellata* individuals from Lisková (loc. 2) and Rybárpole (loc. 3).

	Locality.	Sex	Age	Body length (SVL)	Tail length (TL)	Total length (TotL)	Head length (HL)	Head width (HW)	Mouth length (ML)	PREOC	POSTOC	SUPL	SUBL	VENT	SUBC	DORS	Ventral coloration
1	2	?	subadult	29.5	8.1	37.6	1.6	0.7	1.3	3/3	4/4	8/8	9/9	168	62	19	orange
2	2	?	juvenile	23.6	6.9	30.5	1.2	0.5	1.0	2/2	3/3	8/8	8/8	170	72	19	white - orange
3	2	?	juvenile	25	4.1	29.1	1.3	0.6	1.0	3/3	3/3	8/8	9/9	176	37	19	yellow
4	2	?	juvenile	22.7	5.4	28.1	1.3	0.7	1.1	3/3	4/4	8/8	9/9	167	59	19	white - orange
5	2	?	subadult	28.8	8.1	36.9	1.6	0.7	1.2	2/3	5/4	8/7	9/9	166	66	19	white - orange
6	2	?	juvenile	23.6	6.1	29.7	1.3	0.7	1.1	3/4	3/4	8/9	9/8	161	57	19	orange
7	2	?	juvenile	22.6	5.5	28.1	1.3	0.6	1.1	2/2	3/4	8/8	9/9	166	55	19	orange
8	2	F	adult	73.5	18.6	92.1	3.2	1.8	1.9	2/2	4/4	8/8	9/9	167	63	19	white
9	3	?	juvenile	23.8	6.4	30.2	1.4	0.7	1.1	2/2	4/4	7/7	8/9	163	56	19	white - orange
10	3	?	juvenile	22.6	5.8	28.4	1.2	0.6	1.0	3/3	3/4	8/7	8/8	168	63	19	white - orange
11	3	?	juvenile	24	6.7	30.7	1.4	0.8	1.1	3/3	4/4	8/8	9/9	166	58	19	yellow
12	3	?	juvenile	21.5	7	28.5	1.2	0.5	1.0	2/2	3/3	8/8	9/9	165	71	19	white - orange
13	3	?	juvenile	24.6	7.1	31.7	1.2	0.7	1.1	2/2	3/3	6/7	8/9	167	70	19	yellow
14	3	?	subadult	25.5	7.2	32.7	1.3	0.6	1.1	2/2	4/4	6/6	9/8	172	66	19	white - orange

connection with thermal springs (see Wall 1911). Similar records come from Romania and Hungary where individuals frequently inhabit natural thermal springs (Gruschwitz et al. 1999; Strugariu et al. 2011). Therefore, there is a possibility that the presence of thermal springs near Váh River in the Liptov Basin could provide suitable conditions for the species occurrence and reproduction. As is presented by Vlček et al. (2010), the presence of dark mullock (waste rock acquired in the course of coal mining) is one of the ecological reasons that allows occurrence of isolated populations of this thermophilic species in the northern area of the Czech Republic. This rock absorbs and accumulates heat and creates an optimal microclimate.

Due to expansion ability along climatically beneficial water courses, Dice Snakes may colonize sites even further north. The territory of Slovakia is characterized by structured geomorphology with warm river valleys, separated by high mountains (e.g., Fatra-Tatra area), where the hypsometric temperature gradient reaches significant differences during the day. Open warm valleys probably play a historical role in the colonization of northern and upper Slovak regions for other thermophilous reptiles as *Zamenis longissimus* (Laurenti 1768) or *Podarcis muralis* (Laurenti 1768). Both species were observed in northern Slovak regions (e.g., Kminiak 1992; Rehák 1992b; Astaloš 2002). Moreover, the range of this species was farther to the north in the Lower Pleistocene (see occurrence of *N. cf. tessellata* from Polish Silesia; Ivanov 1997) and probably also during warm periods after the Last Glacial Maximum (Vlček et al. 2011).

In terms of the finding of *N. tessellata* in Ružomberok there should be no problem for individuals to migrate along the riverbank up Liptovská Mara Dam. Dice Snakes can travel along a stretch parallel to the shoreline of 100–500 m in a few days, and max. up to ~1,000 m (Neumann and Mebert 2011; Velenský et al. 2011), and by crawling and swimming can travel even 33 km downstream (Vlček et al. 2011). In Switzerland Conelli et al. (2011) and in the Czech Republic Velenský et al. (2011) recorded *N. tessellata* individuals overcame great movements in the summer, but in spring and autumn they increased migratory distances to and from their hibernacula. For example, in Orava (northernmost region in Slovakia), we recorded anonymous observation of the species near Oravský Podzámok. The published record of the dead individual of the species found near Poprad city (elevation almost 700 m) is probably a case of artificial introduction (Rindoš and Jablonski 2014). However, we cannot exclude a case of natural dispersion into this region because surroundings of Poprad River meet ecological requirements for occurrence of Dice Snakes in Central Europe. Average daily temperature during the hottest month of the year (July) in the last ten years was 17.4 °C in Poprad (18.6 °C in Ružomberok; Slovak Hydrometeorological Institute 2018). Although elevational difference between these two cities is approximately 150–200 m, no popula-

tion of *N. tessellata* is confirmed in Poprad. On the other hand, and in view of herein described records from upper Váh River and Liptovská Mara Dam (approximately 70 km from Poprad city), we cannot exclude migration along the Sub-Tatra Basin. In view of these records, subsequent mapping of *N. tessellata* along the Váh River and other rivers in the country together with genetic research is therefore needed.

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